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Vasomotor Reflexes Elicited by Heat and Cold from Areas Deprived of Temperature Sensibility by a Traumatic Lesion

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VASOMOTOR REFLEXES ELICITED BY HEAT AND COLD FROM AREAS DEPRIVED OF TEMPERATURE SENSIBILITY BY A TRAUMATIC LESION *

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In a pathological case already reported in this journal[1] it was shown that vasomotor reflexes, small but definite, could be elicited by the application of heat or cold to areas totally devoid of temperature sensibility. The present communication establishes the same fact, for an otherwise normal subject, in whom anesthesia of certain portions of one hand had been caused by accidental injury to the median nerve in the fore-arm.

CASE REPORT

History.—The subject, O. C. W., is a healthy fourth-year medical student, aged 24. September 15, 1912, at 9:30 a. m., he injured his left arm by the breaking of a carboy full of water which he was carrying. The main wound was on the front of the lower part of the forearm. In addition there was a small wound on the dorsal aspect of the little finger. From the way in which the carboy was being held the tendons in the lower part of the forearm and at the wrist were on the stretch and stood out, so that they could easily be severed by a relatively superficial wound. The bleeding, so far as could be observed, was entirely venous and capillary. Certainly no large artery was cut. The hemorrhage was controlled by the patient himself by pressure around the wrist with the right hand until assistance was procured. He was taken to a hospital and under gas anesthesia eight flexor tendons which were found divided were sutured, and in addition the tendon of the extensor digiti quinti propius on the dorsum of the little finger. A careful search was made in the wound for divided nerves but no large nerve was found. The wound was closed and a splint put on the arm and hand. The arm was dressed morning and evening for the first few days and afterward each day, and healing occurred without complication.

During the interval (4½ hours) between the injury and the operation the patient was able to make the following observations.

Motor Changes.—Immediately after the accident it was impossible to flex either the thumb or the index finger or any of their phalanges, but adduction and abduction of the thumb and index were not impaired. The middle, ring and little fingers could be flexed, the deep tendons being intact. The hand could not be flexed on the wrist. The little finger could not be extended.

Sensory Changes.—The entire index finger became numb immediately. This numbness later involved more or less the whole of the hand, but was most marked on the radial side of the palmar aspect.

The patient continued from time to time to make observations.

September 20, 1912. The numbness, except on the index finger, has changed into an intense burning and tingling sensation which involves the thumb, middle finger, radial side of ring finger and the radial half of the palm. The little finger

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* From the H. K. Cushing Laboratory of Experimental Medicine, Western Reserve University.

1. Stewart and Laffer: THE ARCHIVES INT. MED., 1913, xi, 365.

and the ulnar half of the palm are not involved in this sensation and the same is true of the dorsal, ulnar and palmar surfaces of the ring finger. The skin over the area involved in this sensation as well as that over the index finger is very dry. The furrows of the skin in this region are noticeably white. There is some swelling in the index and middle fingers.

September 30, 1912. The splint was removed to-day. The sensation of burning and tingling remains the same and is limited as above described. It is like the pain of a burn exposed to the air and is worse at night. The skin has the same appearance as before and is still very dry. On the palmar surface of the third phalanx of the middle finger a small area about 1 cm. in diameter can now be delimited which is very sensitive to light stroking (cotton wool or brush). This hypersensitive spot was first noticed in the latter part of the first week. This area and the rest of the phalanx are anesthetic as regards pain (pin prick), deep pressure, heat and cold. The anesthetic area (to touch, pain, pressure, heat and cold) involves the palmar surface of the thumb, the radial half of the palm, the palmar surface of the index and middle fingers and the entire periphery of the second and third phalanges of the index and middle fingers. The radial side of the ring finger has a certain degree of hypesthesia. The involved area is more or less sensitive to light stroking, the middle finger most, the index finger least. On the middle finger especially such stroking is quite painful while hard rubbing causes no pain. A mere touch on the middle finger, especially the palmar surface, caused discomfort, whereas prolonged stroking or (light) rubbing was necessary to produce the same sensation on the index finger. This hypersensitive condition appeared about the second week while the splint was still on. Sensation is normal on the dorsum of the thumb up to and around the nail, also on the dorsum of the first phalanx of the index and middle fingers. The sides of the first phalanx of the index and middle fingers are normal. The skin over the involved area is desquamating. Motion of the whole hand and of the fingers is greatly limited.

October 10, 1912. Motion much improved. Sensation the same as before, but the painful sensations are less intense. The palm and palmar surface of the middle finger are not so sensitive to light contact (stroking). Cannot localize contact. Cannot distinguish pressure at two points. Thermic sensation absent in the entire involved area.

October 20, 1912. Motion better. Can flex all fingers into the palm. Deep flexor tendon to index does not work, does not flex the terminal phalanx. Tactile sensibility is not appreciably improved. Localization and discrimination of the shape, etc., of a body touching the skin are absent.

November 10, 1912. Motion better. Otherwise no change.

December 10, 1912. Skin over the involved area not so dry. Obviously there is now some sweat secretion but still much less than on the normal skin. Occasional shooting pains starting about the wound and shooting to the ends of the index and middle fingers. On tapping lightly over the scar a sensation similar to that caused by a weak electric shock is transmitted to the ends of the index and middle fingers, never transmitted elsewhere.

December 19, 1912. Accidentally burnt the palmar surface of the terminal phalanx of the index finger. The finger was in contact with a radiator and the patient was quite unconscious it was being burnt. A large blister formed in about an hour.

December 20, 1912. The blister was opened and drained by puncturing with a needle through healthy skin at the side. It began to fill immediately and in a few minutes was as large as before. It was reopened and filled again very quickly and this process was repeated about fifteen times during the day.

December 21, 1912. The skin over the blister was cut off and the accumulation of liquid stopped at once. There was no recurrence of the formation of liquid. No pain was felt from the burn at any time. It was so deep as to involve the fat pad. By January 7, 1913, the burn was completely healed.

December 23, 1912. The distribution of sweat secretion and sensation was carefully tested in the laboratory.

Sweat Secretion.—There is no question that the area deficient in sweat secretion is much smaller than at first, or even than a month ago. The hand was wrapped in a towel after being wiped dry and put into a hot-air oven. The oven contained a dish of water to help to keep the air moist and thus hinder evaporation of the sweat. Sweat secretion is still small or absent over an area on the ball of the thumb about 3½ cm. long by 2 cm. broad. The edge of this area approaches the cleft between the thumb and index finger. On the rest of the radial portion of the palm and on the second and third phalanges of the middle finger, where sweating was absent before, it is now present to a certain extent.

Sensation, Radial Half of Palm.—The small area on the ball of the thumb in which sweat secretion is absent is totally insensitive to light touch (with blunt pencil point, cotton wool or brush). To pressure it is sensitive. If a blunt point is pressed down with more than a certain amount of force the pressure sensation goes on to definite though delayed pain sensation. This area is less sensitive to pressure than the rest of the ball of the thumb. With a tube containing water at 3 C. no cold sensation on this small area, but with a chip of ice a sensation of cold is obtained though delayed. No sensation of warmth with a tube containing water at 45 C., nor was there any effect for some distance outside the boundary. Hotter water (50 C.) is felt as warm on points just outside although not felt at all inside the boundary, whereas elsewhere on the palm it is felt as hot. The rest of the radial half of the palm is sensitive to touch (light contact of blunt point, light stroking with cotton or brush), pressure (with rubber pad of pencil), pain (pin-prick), heat and cold (chip of ice). While ice causes cold sensation everywhere on the palm of the hand it is somewhat less marked on the ball of the thumb and over the radial half of the palm than over the rest of the palm, rather a cool sensation than that of ice.

The thumb is sensitive to light touch but on the palmar surface of the second phalanx, although a tactile sensation is elicited, the subject cannot tell anything about the kind of body touching him; for example, whether it is pointed or not. Pressure sensation is fair on the palmar surface of the thumb and good on the dorsum. Ice gives no sensation of cold on the palmar surface of the second phalanx; elsewhere the normal sensation. The pin-prick, which elsewhere on the thumb causes pain, elicits only the sensation of contact on the palmar surface of the second phalanx.

The little finger is normal. The more detailed examination of the remaining three fingers follows.

Light Touch.—Index Finger, Palmar Surface.—On the second and third phalanges no sensation to simple touch but some sensation to pressure, not going on to pain even with strong pressure with a blunt point. On the first phalanx touch is felt but the shape of the object is not discriminated. *Dorsal Surface.*—Third phalanx only slight sensation of touch without discrimination of nature of object. Second phalanx much better touch sensation. First phalanx normal. *Ulnar Surface.*—Third phalanx no tactile sensation. Second phalanx fair, third normal. *Radial surface.*—Third phalanx poor tactile sensation, second pretty good, first normal.

Middle Finger.—Hyperesthetic to light touch on palmar aspect, elsewhere much the same as the index.

Light stroking with cotton wool or brush shows much the same distribution of anesthesia over the whole involved area as in the other tests.

Cold.—Index, Palmar Surface.—Second and third phalanges no cold sensation to ice. First phalanx, little if any cold sensation, perhaps a slight sensation after a long application of the ice. *Dorsal and Radial Surfaces.*—Second and third phalanges no cold sensation. First phalanx normal. *Ulnar Surface.*—Second and third phalanges, no cold sensation. First phalanx, cold sensation but delayed.

Middle Finger, Palmar Surface.—No cold sensation on any of the phalanges, but the contact of ice gave a sensation of touch on all. *Dorsal, Radial and Ulnar Surfaces.*—Second and third phalanges, no cold sensation; first phalanx normal.

Ring Finger.—Palmar, dorsal and ulnar surfaces normal. *Radial Surface.*—First and third phalanges normal; a small area about 5 mm. distal to the joint between the first and second phalanges on the radial side and overlapping the dorsal surface of the second phalanx either gives no cold sensation with ice or the sensation is markedly delayed.

The application of a point of ice to the point on the scar in the forearm, mechanical stimulation (tapping) of which gives a sensation like a weak electric shock running down to the index and middle fingers causes no effect except a local sensation of cold over the point touched. On no part of the anesthetic area is anything except a local sensation of cold obtained on contact with ice. No "peripheral reference" of cold[2] could be demonstrated at this stage at any part of the anesthetic area.

Warmth (warm tube).—Index Finger, Palmar Surface.—No sensation of warmth on any phalanx. Sensation of contact on first phalanx. *Dorsal Surface.*—Warmth felt on first phalanx, nothing on second and third.

Middle Finger.—The same portions are sensitive to warmth as to cold and in about the same degree.

Ring Finger.—Normal except the small area on the second phalanx which was insensitive to ice. This area gives the sensation of warmth with a tube which elsewhere gives a hot sensation.

Pain (pin-prick).—Index Finger, Palmar Surface.—Only sensation of contact is given on first phalanx except with considerable pressure, when pain is elicited. Second and third phalanges give only sensation of contact to pin-prick and heavy pressure is required to elicit even this. No discrimination of the nature of the object. *Dorsal Surface.*—First phalanx normal. Second phalanx greater pressure of the pin needed to give pain than on normal skin. Third phalanx no pain, even with considerable pressure; only an indefinite contact sensation.

Middle Finger, Palmar Surface.—All the phalanges are hyperesthetic. A pin-prick gives definite pain, much more intense than on the rest of the skin. Second and third phalanges are more sensitive than the first. Light contact or a light prick gives most pain. Pressing or rubbing hard with a flat surface does not give pain, nor does pinching. Light stroking gives a sensation of exaggerated tickling which is almost pain.

Ring Finger.—Normal to pin-prick except the small area which is abnormal to temperature sensation. On this area a pin-prick gives sensation of contact and not of pain.

Pressure (with rubber pad of pencil).—Index, Palmar Surface.—First phalanx, fair sensation, diminishing on second phalanx toward third phalanx. *Dorsal Surface.*—First phalanx normal. On third phalanx pressure sensation is barely obtainable. Second phalanx intermediate.

Middle Finger, Palmar Surface.—Good pressure sensation on all phalanges but accompanied with tingling. *Dorsal Surface.*—First phalanx normal. Second phalanx fair sensation, and better than on second phalanx of index finger. Third phalanx about the same as second phalanx of index finger; on increasing the pressure the pressure sensation goes on to pain, which is not the case on the second and third phalanges of the index finger.

Ring Finger.—Normal everywhere.

January 21, 1913. Light touch (stroking with brush) is felt over the whole of the involved area but only slightly on the second and third phalanges of the index finger. On the palmar surface of the middle finger the sensation is one of exaggerated tickling. No area can now be found on the ball of the thumb which is insensitive to contact (brush or blunt pencil point). The radial portion of the palm is moist although dryer than the rest of the palm.

2. Trotter and Davies: Jour. Physiol., 1909, xxxviii, 178.

January 24, 1913. Peripheral reference of cold cannot be obtained. Sensation of cold over the scar is delayed.

The subject came under observation of the senior author for the first time, a month after receiving the injury. The first blood-flow examination was made Oct. 15, 1912.

October 15, 1912. The blood flow and vasomotor reflexes of the hands were examined after the subject's day's work as a medical student. Pulse 112 (sitting). Hands in bath at 4:12 p. m. Hands in calorimeters at 4:35 p. m. The hands were kept in the bath for a longer time than usual owing to accidental

TABLE 1.—Calorimetric Tests of Blood-Flow in Hands of O. C. W.

Time.	R.	L.	Notes.
4:34	31.02	31.10	
4:36	31.02	31.10	
4:37	31.04	31.12	
4:38	31.07	31.15	Room 22.6 C.
4:39	31.10	31.19	
4:40	31.13	31.22	Room 22.6 C.
4:41	31.20	31.26	
4:42	31.25	31.31	Room 22.5 C.
4:43	31.31	31.34	
4:44	31.38	31.39	
4:45	31.42	31.43	Room 22.8 C.
4:46	31.46	31.46	
4:47	31.495	31.495	
4:48	31.52	31.52	
4:49	31.535	31.53	
4:50	31.56	31.55	Room 22.9 C.
4:51	31.56	31.56	
4:52	31.585	31.57	Room 22.9 C.
4:53	31.595	31.585	† *
4:54	31.595		Room 22.9 C.
4:55	31.61		
4:56	31.65		
4:57	31.69		Room 23.1 C.
4:58	31.71		
4:59	31.73		Room 23.1 C.
5:00	31.785		
5:01	31.81		Room 23.0 C.
5:02	31.825		At 5:02 anesthetic phalan-
5:03	31.845		ges immersed in water at
5:04	31.89		43.4 C.
5:05	31.91		
5:06	31.96		
5:07	32.01		
5:08	32.08		
5:09	32.11		
5:10	32.16		At 5:10 whole left hand put
5:11	32.18		into water at 42.6 C.
5:12	32.22		Room 23.3 C.
5.13	42,265		
5:14	32.29		
5:15	32.335		
5:16	32.395		
5:17	32.45		
5:18	32.48		At 5:18 whole left hand put into cold water.
5:19	32.495		Room 23.4 C.
5:20	32.505		
5:21	32.535		Felt the cold water sharply
5:22	32.57		at first but is now getting
5:23	32.59		used to it.
5:24	32.60		Room 23.35 C.
5:25	32.61		
5:26	32.625		Hands out of calorimeter at 5:26.
5:38	32.46		Temp. of L. is now 31.04 C.
....	.....		Cooling of R. 0.165 degrees in 12 minutes.
....	.....		Cooling of L. 0.545 degrees in 45 minutes.

† At 4:53 the anesthetic phalanges of left hand immersed in water at 8.2 C.

* The hands were cautiously immersed so that the subject should not feel the cold water, the hand and wrist being kept from contact with the vessel by a towel. On their first introduction into the cold water the anesthetic phalanges were immersed for a moment rather too deeply, so that he felt what he termed a suspicion of cold. The fingers were at once withdrawn a little and thereafter he had no sensation of cold whatever.

delay in the preparations: 3,015 c.c. of water in each calorimeter. Volume of right hand 447 c.c., of left 436 c.c. Rectal temperature 37.15 C. Height 5 feet, 7½ inches. Weight 146 pounds. Came in from street not wearing gloves.

In this experiment immersion of the anesthetic phalanges of the left hand in cold water caused a definite though transient diminution of the flow in the right hand (from 7.39 to 3.82 grams per 100 c.c. per minute) for the first two minutes of immersion. For the next seven minutes

while the anesthetic phalanges continued in the cold water the flow increased to 7.58 grams. For the whole nine minutes the flow was diminished from 7.39 to 6.75 grams per 100 c.c. of hand per minute. The initial flow in the left hand was somewhat less than that in the right (6.83 grams per 100 c.c. per minute). A considerable and more persistant increase in flow followed the immersion of the anesthetic phalanges

TABLE 2.—Calorimetric Tests of Blood-Flow in Hands of O. C. W.

Time.	R.	L.	Notes.
2:11	30.93	30.90	Room 23.1 C.
2:13	30.89	30.93	
2:14	30.93	30.99	Room 23. 3 C.
2:15	30.99	31.04	
2:16	31.06	31.10	Room 23.3 C.
2:17	31.12	31.16	
2:18	31.195	31.205	Room 23.3 C.
2:19	31.265	31.265	Room 23.3 C.
2:20	31.31	31.31	
2:21	31.36	31.34	Room 23.2 C.
2:22	31.40	31.39	Room 23.3 C.
2:23	31.44	31.41	At 2:23 anesthetic phalanges put into water at 8 C.

Time.	R.	Notes.
2:24	31.46	
2:25	31.48	Room 23.3 C.
2:26	31.515	
2:27	31.55	Room 23.3 C.
2:28	31.59	
2:29	31.63	Room 23.2 C.
2:30	31.69	Room 23.3 C.
2:31	31.73	
2:32	31.78	Room 23.3 C.
2:33	31.805	At 2:33 anesthetic phalanges put into water at 43.5 C.
2:34	31.825	
2:35	31.85	
2:36	31.89	
2:37	31.92	
2:39	31.96	Room 23.4 C.
2:39	31.99	
2:40	32.04	
2:41	32.08	Room 23.4 C.
2:42	32.115	
2:43	32.16	Room 23.3 C.
2:44	32.195	At 2:44 whole left hand put in water at 43 C. Room 23.3 C.
2:45	32.32	
2:46	32.265	
2:47	32.30	
2:48	32.355	Room 23.3 C.
2:49	32.395	
2:50	32.44	Room 23.3 C.
2:51	32.51	
2:52	32.57	Room 23.3 C.
2:53	32.61	
2:54	32.67	
2:55	32.705	At 2:55 whole left hand put in water at 8 C.
2:56	32.74	Room 23.1 C.
2:57	32.775	
2:58	32.795	
2:59	32.825	
3:00	32.85	
3:01	32.875	Room 23.3 C.
3:02	32.895	
3:03	32.895	
3:04	32.90	At 3:04 dried and wrapped left hand in warm cloth.
3:05	32.91	Room 23.3 C.
3:06	32.925	
3:07	32.935	Room 23.1 C. He says the left hand feels warm.
3:08	32.955	
3:09	32.97	
3:10	32.975	
3:11	32.975	Room 23.3 C.
3:12	33.02	Hand removed from calorimeter at 3:12.
3:28	32.86	Temp. of L. is now 30.695 C.
....	.....	Cooling of R. 0.16 degrees in 16 minutes.
....	.....	Cooling of L. 0.715 degrees in 65 minutes.
....	.....	Vol. of right hand 431 c.c.
....	.....	Vol. of left hand 407 c.c.
....	.....	Rectal temperature 37.05 C.

in the warm water (from 7.58 to 10.58 grams per 100 c.c. of hand per minute for a period of eight minutes). When the whole left hand was now immersed in the warm water some further increase in the flow of the right hand (to 11.14 grams per 100 c.c. per minute for a period of eight minutes) ensued, and this was promptly cut down to 7.24 grams when the whole left hand was immersed in the cold water. Not only was the diminution greater when the whole hand was immersed, but it was

also more persistent than when the anesthetic phalanges alone were exposed to the cold water.

After an interval of two months another examination was made.

December 19, 1912. Tested thermal sensibility of left hand before the experiment. No sensation to immersion in warm or cold water on middle finger, at least up to the upper third of the second phalanx. On the index finger no sensation on immersion at least up to a level well above the second interphalangeal joint. A perfectly safe level of immersion was thus determined beforehand. An hour before he had burned the flexor surface of the third phalanx of the index finger on a radiator without knowing it and there was a blister on it. He washed his hands in warm water before they were put into the bath at 2 p. m. Pulse 104 (sitting). Hands in calorimeter at 2:12. In testing, the anesthetic phalanges were passed through a hole in a thick plate of cork to avoid contact of sensitive skin with the vessel or water.

TABLE 3.—Experiment 3 with Right Hand in Calorimeter.

December 21, 1912. Right hand put into bath at 11:18 a. m. Left hand in air. Pulse 104 (sitting). At 11:28½ right hand put into calorimeter.

Time.	R.	Notes.
11:28	30.60	
11:29	30.53	Room 22.7 C.
11:30	30.54	Room 22.9 C.
11:31	30.57	
11:32	30.625	Room 22.9 C.
11:33	30.69	
11:34	30.75	Room 22.9 C.
11:35	30.795	
11:36	30.855	
11:37	30.91	
11:38	30.97	Room 22.9 C.
11:39	31.02	
11:40	31.07	At 11:40 anesthetic phalanges put in water at 8.1 C. No sensation.
11:41	31.095	Room 22.9 C.
11:42	31.12	
11:43	31.165	Room 23 C.
11:44	31.205	
11:45	31.25	Room 22.8 C.
11:46	31.305	
11:47	31.365	Room 22.8 C.
11:48	31.42	
11:49	31.49	
11:50	31.53	At 11:50 anesthetic phalanges put in water at 42.8 C.
11:51	31.55	
11:52	31.59	Room 22.6 C.
11:53	31.62	
11:54	31.675	Room 22.6 C.
11:55	31.73	Room 22.5 C.
11:56	31.77	
11:57	31.81	Room 22.5 C.
11:58	31.87	
11:59	31.915	
12:00	31.965	At 12:00, 7 phalanges of left hand put in water at 42 C.
12:01	31.995	
12:02	32.02	Room 22.7 C.
12:03	32.06	Room 22.8 C.
12:04	32.10	
12:05	32.155	
12:06	32.20	
12:07	32.26	Room 23 C.
12:08	32.25	
12:09	32.32	Room 23.1 C.
12:10	32.35	
12:11	32.39	
12:12	32.43	Room 23.1 C. At 12:12 the 7 phalanges put in water at 8.2 C.
12:13	32.46	
12:14	32.48	
12:15	32.51	Room 23.2 C.
12:16	32.535	
12:17	32.56	Room 23.35 C.
12:18	32.585	
12:19	32.605	
12:20	32.63	Room 23.3 C.
12:21	32.655	At 12:21 whole left hand put in water at 43 C.
12:22	32.68	
12:23	32.705	Room 23.4 C.
12:24	32.74	
12:25	32.78	
12:26	32.82	
12:27	32.86	Room 23.3 C.
12:28	32.90	
12:29	32.945	Room 23.2 C.
12:30	33.02	Hand out of calorimeter at 12:30.
12:44	32.86	
.....	.....	Cooling of calorimeter R 0.16 degrees in 14 minutes.
.....	.....	Cooling of control calorimeter (without hand) from 30.53 to 29.76 degrees, or 0.77 degrees in 71 minutes.
.....	.....	Rectal temperature 37 C.
.....	.....	Vol. of right hand 431 c.c.

In the experiment of December 19 the flow for ten minutes before the vasomotor reflex was tested was 10.63 grams per 100 c.c. per minute for

the right hand and 10.23 grams for the left. For the first two minutes of immersion of the anesthetic phalanges of the left hand in cold water the flow in the right hand sank to 5.21 grams, rising again to 9.15 grams per 100 c.c. per minute for the remaining eight minutes during which the anesthetic phalanges continued in the cold water. On transferring the anesthetic phalanges to warm water the flow in the right hand diminished for the first four minutes to 7.80 grams per 100 c.c. per minute, to increase again to 9.45 grams for the remaining seven minutes of the period of immersion. When the whole left hand was immersed in

TABLE 4.—Summary of Blood-

Date.	Temp. C. of Calorimeter				Vol. of Hands, c.c.		Heat given off (small cals.)		
	Room.	R.	L.	Art. Blood.	R.	L.	R.	L.	In mins.
Oct. 15	22.6	31.32	31.35	36.65	447	436	2537	2273	16
	22.8	31.61	.....	.....	...	...	155	....	2
	22.9	31.72	.....	.....	...	...	1053	....	7
	23.0	31.87	.....	.....	...	...	431	....	3
	23.1	32.04	.....	.....	...	...	1157	....	5
	32.2	32.23	.....	.....	...	...	638	....	4
	23.2	32.39	.....	.....	...	...	915	....	4
	23.3	32.55	.....	.....	...	...	956	....	8
Dec. 19	23.3	31.17	31.17	36.55	431	407	2219	2018	10
	23.3	31.46	.....	.....	...	...	206	....	2
	23.3	31.64	.....	.....	...	...	1394	....	8
	23.3	31.87	.....	.....	...	...	567	....	4
	23.35	32.06	.....	.....	...	...	1153	....	7
	23.3	32.25	.....	.....	...	...	464	....	3
	23.3	32.50	.....	.....	...	...	1669	....	8
	23.2	32.81	.....	.....	...	...	1032	....	9
	23.25	33.01	.....	.....	...	...	1032	....	8
Dec. 21	22.9	30.82	.....	36.50	431	...	2012	....	9
	22.9	31.10	.....	.....	...	...	242	....	2
	22.9	31.33	.....	.....	...	...	1684	....	8
	22.6	31.58	.....	.....	...	...	416	....	3
	22.5	31.79	.....	.....	...	...	1448	....	7
	22.7	31.99	.....	.....	...	...	263	....	2
	22.95	32.23	.....	.....	...	...	1782	....	10
	23.25	32.54	.....	.....	...	...	1110	....	9
	23.35	32.70	.....	.....	...	...	440	....	3
	23.25	32.98	.....	.....	...	...	1160	....	6

the warm water the flow in the right hand for the first three minutes was 9.27 grams, which increased to 13.27 grams per 100 c.c. per minute for the remaining eight minutes of the period. The whole left hand was then put into cold water and the flow in the right sank to 7.90 grams per 100 c.c. per minute during the nine minutes of immersion, to rise again to 9.39 grams (over a period of eight minutes) when the left hand was dried and wrapped up.

In both of the above experiments the two hands were originally in the calorimeters. In order to test the effect of the immersion on the anesthetic phalanges alone, the left hand had to be taken out and dried.

Although the drying was carefully done, it might be objected that the effect on the flow in the right hand following the first immersion of the anesthetic phalanges was really due to stimulation of the temperature nerves in the normal portions of the still moist left hand. Of course, this possibility could only apply to the first immersion of the anesthetic phalanges and not to succeeding immersions. Yet it was considered desirable to eliminate it and this was done in the experiment of Dec. 21, 1912, in which only the right hand was put into a calorimeter, the left being kept dry until the moment for immersion of the anesthetic phal-

Flow Observations on O. C. W.

Flow in Hands per min.		Flow per 100 c.c. per min.		
R.	L.	R.	L.	Notes.
33.05	29.78	7.39	6.83	Before vasomotor reflex tests.
17.08	.....	3.82	.....	Anesthetic phals. in cold water (first 2 mins.).
33.90	.....	7.58	.....	Anesthetic phals. in cold water (next 7 mins.).
33.39	.....	7.24	.....	Anesthetic phals. in warm water (first 3 mins.).
55.77	.....	12.47	.....	Anesthetic phals. in warm water (next 5 mins.).
40.09	.....	8.96	.....	Whole left hand in warm water (first 4 mins.).
59.66	.....	13.34	.....	Whole left hand in warm water (next 4 mins.).
32.38	.....	7.24	.....	Whole left hand in cold water
45.82	41.67	10.63	10.23	Before vasomotor reflex tested.
22.48	.....	5.21	.....	Anesthetic phals. in cold water (first 2 mins.).
39.43	.....	9.15	.....	Anesthetic phals. in cold water (next 8 mins.).
33.65	.....	7.80	.....	Anesthetic phals. in warm water (first 4 mins.).
40.76	.....	9.45	.....	Anesthetic phals in warm water (next 7 mins.).
39.96	.....	9.27	.....	Whole left hand in warm water (first 3 mins.).
57.23	.....	13.27	.....	Whole left hand in warm water (next 8 mins.).
34.06	.....	7.90	.....	Whole left hand in warm water (first 3 mins.).
40.49	.....	9.39	.....	Whole left hand dried and wrapped up.
43.73	.....	10.14	.....	Before vasomotor tests.
24.89	.....	5.77	.....	Anesthetic phals. in cold water (first 2 mins.).
45.26	.....	10.50	.....	Anesthetic phals. in cold water (next 8 mins.).
31.31	.....	7.28	.....	Anesthetic phals. in warm water (first 3 mins.).
48.79	.....	11.32	.....	Anesthetic phals. in warm water (next 7 mins.).
32.39	.....	7.51	.....	7 phals. left hand in warm water (1st 2 mins.).
46.37	.....	10.75	.....	7 phals. left hand in warm water (next 10 min.).
34.60	.....	8.02	.....	7 phals. of left hand in cold water.
43.27	.....	10.04	.....	Whole left hand in cold water.
61.02	.....	14.15	.....	Whole left hand in warm water (next 6 mins.).

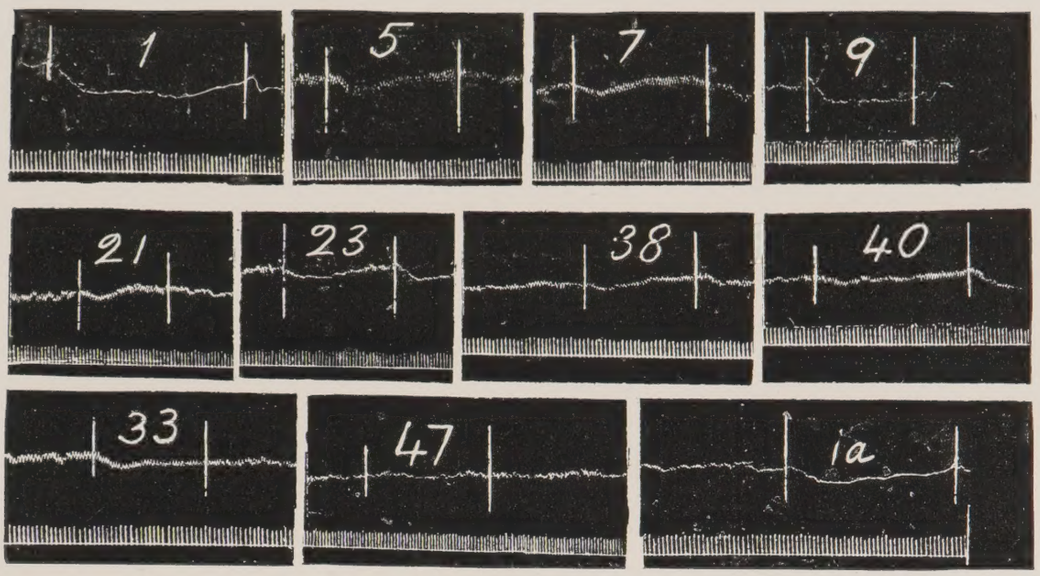
anges. As in the previous experiment, a sheet of thick cork with a hole through which the anesthetic phalanges passed prevented any contact of the rest of the hand with the cold or warm water or the container.

It will be seen that the results are precisely the same as in the other experiments. For nine minutes before testing the vasomotor reflex the flow in the right hand comes out 10.14 grams per 100 c.c. per minute. For the first two minutes of immersion of the anesthetic phalanges of the left hand in cold water, the flow in the right sinks to 5.77 grams, to increase to 10.50 grams per 100 c.c. per minute for the remaining eight

minutes of immersion. When the anesthetic phalanges were now immersed in warm water (the change from the cold to the warm water was made instantaneously without taking the phalanges out of the cork) the flow diminished for the first three minutes to 7.28 grams, to increase to 11.22 grams per 100 c.c. per minute for the remaining seven minutes of the period of immersion. Immersion in warm water of seven phalanges (second and third of index, middle and ring, and third of little finger) of the left hand, including the anesthetic phalanges, caused now a diminution of the flow in the right hand for the first two minutes to 7.51 grams per 100 c.c. per minute. For the remainder of the period during which these phalanges continued in the warm water (ten minutes) the flow rose to 10.75 grams per 100 c.c. per minute. For nine minutes during the immersion of these phalanges in cold water the flow in the right hand declined to 8.02 grams, a more persistent diminution than was caused by immersion of the anesthetic phalanges alone. When the whole left hand was subsequently put into warm water, an increase ensued in the flow in the right hand to 10.04 grams per 100 c.c. per minute for the first three minutes and 14.15 grams for the remaining six minutes of immersion, the greatest flow witnessed throughout the observation on this case.

In all three experiments, then, a change is produced in the blood-flow in the right hand when a portion of the left hand, totally insensitive to warmth or cold (as well as to other forms of sensation), is immersed in warm or cold water. Although the effect is smaller and more transient than that produced by immersion of the sensitive portions of the left hand, it is too definite to be attributed to accidental changes in the circulation.

The question has already been raised in discussing a similar reaction elicited from parts totally devoid of temperature sensibility in a pathological case,[1] whether afferent impulses capable of affecting vasomotor centers can be conducted by the nerves of warmth and cold sensation when they are unable to conduct impulses, at least in sufficient intensity, which give rise to temperature sensations, or whether the reactions are elicited through nerves, for example, those supplying the deeper structures, which can be excited by abrupt variations of temperature, although no result is produced in consciousness, and which can act as the afferent link in the vasomotor reflex arc. The possibility also presented itself that the blood in the anesthetic phalanges was sufficiently cooled or heated during the immersion to cause excitation of nerve endings in parts above the level of the anesthesia. In regard to this last possibility it must be remarked that since no sensation of heat or cold was experienced in such neighboring parts, the suggestion is really included in the ques-



Description of Figure 1.—Finger plethysmograph tracings. The tracings are to be read from left to right. The periods of immersion of the parts to which cold or warm water was applied are indicated by the vertical lines drawn through the curves. The signal trace which marked the moment of immersion and withdrawal has been omitted. Time is marked in seconds.

1. Right middle finger of S., a normal man, in plethysmograph. Left hand in cold water (8 C.) for the period comprised by the vertical lines drawn through the curve. The shrinking of the finger (fall of the curve) is evident.

5. Right middle finger of W. in plethysmograph. Whole left hand in cold water (8 C.).

7. Right middle finger of W. in plethysmograph. The anesthetic phalanges of left hand in cold water (8 C.).

9. Right middle finger of S in plethysmograph. Distal half of left hand in cold water (8 C.).

21. Right middle finger of W. in plethysmograph. Anesthetic phalanges of left hand in warm water (45 C.).

23. Right middle finger of W. in plethysmograph. Second and third phalanges of ring, and third phalanx of little finger of left hand in warm water (45 C.).

33. Right middle finger of W. in plethysmograph. The anesthetic phalanges of left hand in cold water (8 C.).

38. Right index finger of W. in plethysmograph. Anesthetic phalanges of left hand in warm water (43 C.).

40. Right index finger of W. in plethysmograph. Second and third phalanges of ring finger and third phalanx of little finger of left hand in warm water (43 C.).

47. Second and third phalanges of left index finger of W. in plethysmograph. Whole right hand in cold water (6.5 C.).

1-a. Right middle finger of W. in plethysmograph. The anesthetic phalanges of left hand in cold water (6.9 C.). This was the first immersion of the phalanges.

tion as already stated. In the hope of throwing some light on this question plethysmographic observations were made with a view of determining the latent period of the contralateral reflex elicited from the anesthetic phalanges. A finger plethysmograph was adjusted on the opposite hand. The moment of immersion of the anesthetic phalanges was written above the plethysmogram by an electromagnetic signal. It was foreseen that unless this latent period should turn out to be markedly lengthened no deductions could be drawn as to whether conduction of heat to or from a deeper layer than usual or convection of heat in the blood to neighboring parts was essential. For we neither know how rapidly heat would be conducted through a finger with the circulation going on, nor how great a change of temperature would be necessary to excite nerves which gave no sign by a sensation of temperature when the threshold had been reached. As a matter of fact, the latent period turned out to be quite small and not measurably greater than when the reaction was elicited from normal skin (Fig. 1). The description of the figure sufficiently elucidates the results. It is, however, worthy of special remark that when the second and third phalanges of the index finger of the left hand were enclosed in the plethysmograph no vasomotor reflex could be elicited from the right hand, even when the whole of that hand was immersed in warm or cold water. The meaning of this can only be that the efferent vasomotor fibers going to the index finger or their endings have not yet regenerated to the point at which they can conduct effective impulses. It is entirely in accordance with this that the spontaneous variations in the finger volume not connected with the respiratory movements and with a period covering several respirations which sometimes appear on the trace of the right middle finger, are absent from the trace of the left index finger. If these non-respiratory waves represent more or less rhythmical variations in vasomotor tone they must be absent from a part whose efferent vasomotor fibers are eliminated. We thus arrive at the conclusion that at a time when the efferent vasomotor fibers of a given part have not regenerated, afferent impulses from the same part elicited by heat or cold and producing no effect in consciousness can cause vasomotor reflexes. It must be remembered that the efferent vasomotor fibers in question are autonomic fibers whose cells of origin are in sympathetic ganglia, whereas the afferent fibers are cerebrospinal, their cells of origin being in the posterior root ganglia. In connection with the vasomotor paralysis of the anesthetic phalanges, the extremely rapid and persistent transudation of liquid into the blister on the terminal phalanx of the index finger is a matter of interest. The normal healing of the region, for it was not in the least delayed nor did any complication what-

ever appear, does not tally with the idea that any essential trophic influence had been removed by the injury to the cutaneous nerves.[3]

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3. Additional note.—March 19, 1913. Peripheral reference of cold (to the tip of the index finger) has now been observed for the past ten days when a cold object touches a definite part of the scar in the forearm. It is elicited by the point (2 mm. in diameter) of a cylinder filled with ice but more intensely with a larger surface. The local response is inferior in intensity to the referred sensation. No peripheral reference of heat is obtained (confirmatory of Trotter and Davies[2]). No peripheral reference of cold as yet from any other part of the skin. The second and third phalanges of the middle and index fingers still give no response to hot or cold cylinders. But prolonged immersion in water at 43 C. (as in the blood-flow measurements) now causes the slow development of "something like a warm sensation," and in water at 8 C. "tingling as if from cold." Light stroking, contact with a blunt point, and pressure are now appreciated over the whole hand. The index finger is now hypersensitive to stroking (except the dorsum of the third phalanx) and appreciates pain on very strong pressure, as on biting the finger. Blood-flow observations in the hands show essentially the same features as at the previous examinations.